Risk-based Safety Model: Applicable Risk Quantification in Motion Planning

Background

The safe deployment of autonomous vehicles relies on the development of robust risk estimation models that can consider the uncertainties of dynamic and unpredictable environments. Risk in autonomous driving could be defined as the combination of the probability of occurrence of harm and the extent of that harm [1]. These models are vital for detecting potential hazards and enabling reliable decision-making across diverse scenarios. A key element within many of these frameworks is intention prediction, including behavior and trajectory prediction. This process anticipates the movements of surrounding agents while integrating uncertainty into the overall risk evaluation. Together, these components help minimize accident likelihood and enhance operational safety.

Description

We aim to develop a unified risk-quantification framework for autonomous driving that jointly integrates behavior-aware trajectory prediction, uncertainty and risk quantification, and risk-informed planning. The system will predict both continuous trajectories [2] and discrete behaviors [3] of surrounding agents while capturing aleatoric and epistemic uncertainties. These uncertainty-aware predictions will be fed into dynamic risk field models (e.g., EDRF [4]) to compute spatiotemporal risk distributions, which will guide adaptive motion planning and decision-making. The framework will be validated in CARLA simulator environments as well as with real-world data using urban and highway scenarios with occlusion, ambiguous behaviors, and sensor limitations.

For this position, you will find a way to integrate the quantified risk field and uncertainty into motion planning, e.g., turning it into a cost field, and validate its impact using the CARLA simulator.

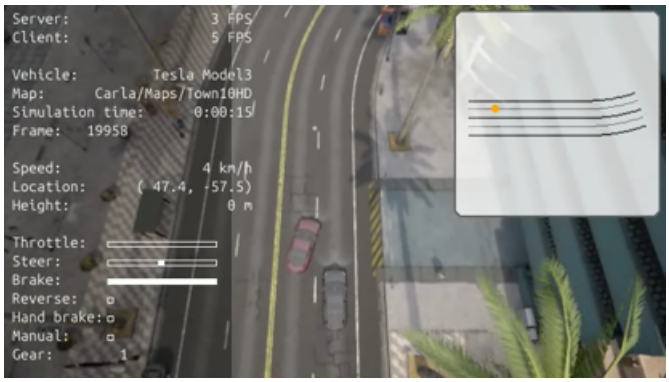

Figure 1: Bird's Eye View of an example scenario.

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Research project:
Risk-based Safety Model

Type:
BA/MA/GR

Research area:
autonomous driving risk, risk-aware planning, uncertainty and reliability, automotive

Programming language:
Python

Required skills:
Programming skills in Python (must have); Experience with probabilistic modeling, motion planning, risk field modeling, CARLA simulator. (nice to have).

Language:
English

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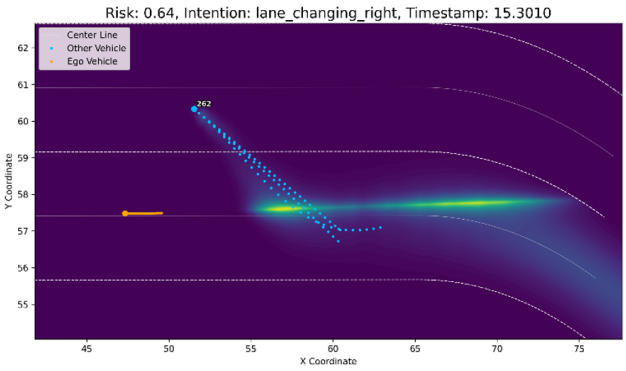

Figure 2: Example risk field of the time step.

Tasks

- Implement dynamic risk field models (e.g., DRF [5], EDRF [4]) using road topology and trajectory and behavior predictions.
- Convert risk maps into cost maps for planners, test risk-aware planning, and validate the safety performance after integrating the risk.
- Simulate realistic urban driving in CARLA, including occlusion scenarios and intention ambiguity.
- Analyze results using benchmarks like SafeBench [6] and RiskBench [7].

References

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